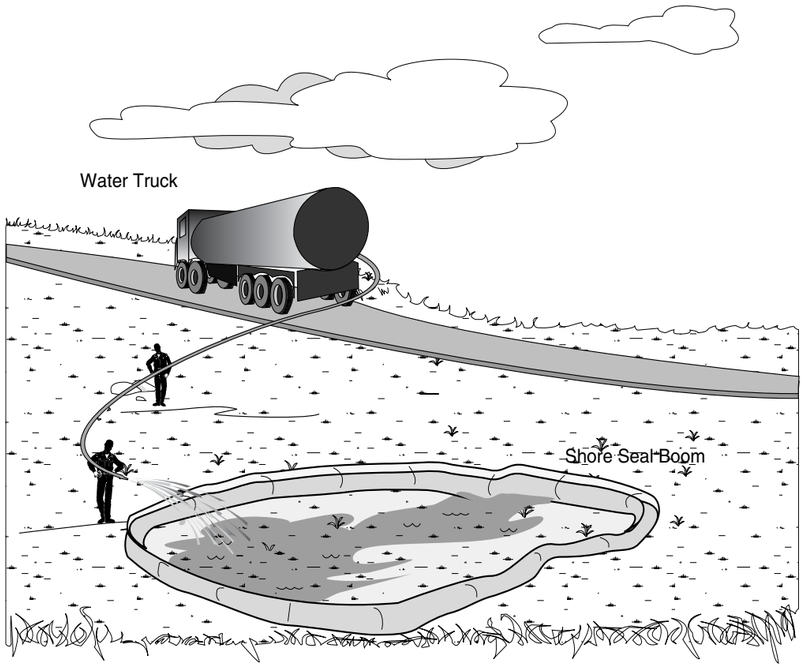


Use flooding to introduce water onto the tundra at a spill site. The nature of the spilled substance determines the purpose of flooding:

- *Crude Oil and Diesel Spills*: Flooding raises or maintains the water level in the tundra to reduce the infiltration of oil into the root zone and subsurface soil or to reduce the amount of oil contacting vegetation foliage. The floating oil then can be recovered with skimmers (Tactic T-7) or sorbents (Tactic T-4). Repeated flooding and pumping have been shown to greatly increase recovery of spill residue.
- *Water-Soluble Substances (methanol, glycol, salts)*: Flooding dilutes spills to reduce the toxicity to the tundra. The diluted spill can be recovered by repeated flooding and pumping (Tactic T-7).

Generally, low pressures and cold or warm (<106°F) water temperatures are used. Water may be obtained from a nearby tundra pond or creek. Do not use seawater or produced water to flood tundra vegetation. Flooding must be contained using land barriers (Tactic T-3).

Note that flooding is different than *flushing* (Tactic T-2).

Flooding may also be used to irrigate (Tactic T-15) a site during the growing season.

APPLICABILITY

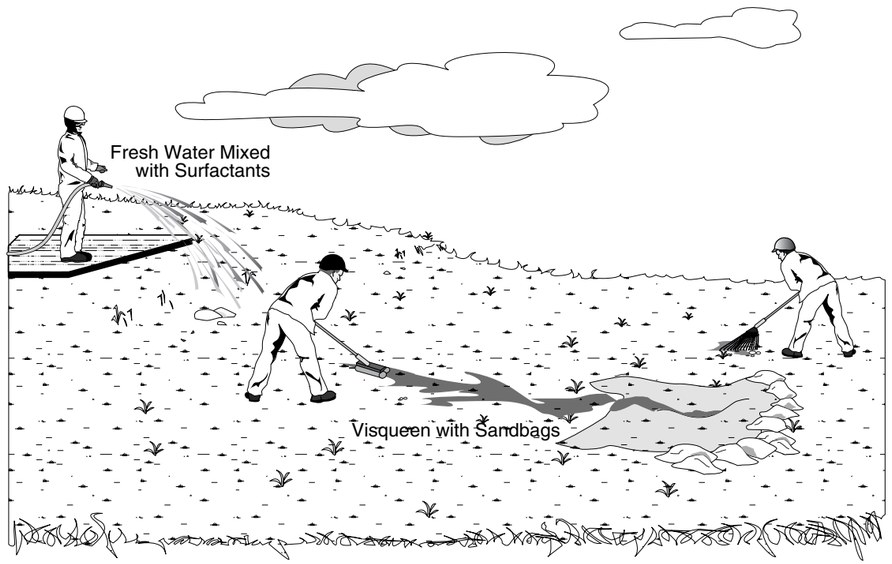
	APPLICABILITY	COMMENTS
SPILLED SUBSTANCE	All	• Weathered crude oil may mix with the water. • Diesel may float initially but will mix with the water.
TUNDRA TYPE	All	• In dry tundra, saturation of pore spaces in root mat or soil will decrease space for contaminant to occupy. • In wet tundra, flooding will increase water levels to make skimming more effective.
SEASON	Spring, summer, fall	• Frozen soil should not be thawed to the point that contamination can infiltrate root mat. • Flooding is a viable option only when air temperatures permit.

CONSIDERATIONS AND LIMITATIONS

- Avoid impacting higher topographical features (e.g., raising the water level in a spill-affected area may expose initially unaffected tussocks).
- Avoid high water pressures (>50 pounds per square inch) that could damage tundra.
- **Warm water** (<106°F) may be more effective than cold water (Alaska Clean Seas, 1999).
- Ensure that land barriers (Tactic T-3) are built to withstand increased water content in the spill area.
- This tactic has been adapted from Tactic R-4 in the *Alaska Clean Seas Technical Manual* (Alaska Clean Seas, 1999, Vol. 1) and has been used in treating crude-oil-affected moist and wet tundra on the North Slope with acceptable short-term results (Jorgenson and Cater, 1996; Cater and Jorgenson, 1999). Information on the effectiveness of this tactic is based on field observations, not controlled experiments. No test data exist which document whether the use of this tactic results in long-term benefits to tundra restoration compared with other tactics, combinations of tactics, or “no action.”

EQUIPMENT, MATERIALS, AND PERSONNEL

- Water truck or upright tank (1 operator) - to provide water source
- Pumps and suction and discharge hose (1 to 2 operators each)
- Land barriers (Tactic T-3)
- Clean water (not saltwater)



Flushing with surfactants is essentially a wash-up tactic to be used after the majority of the spilled product has been removed using other methods. Surfactants can increase the ability of water to dissolve non-miscible products and can reduce adhesion of crude oil and fuels to vegetation. Flush with warm water (<106°F), if available, at high volume (50 to 250 gallons per minute) and low pressure (<50 pounds per square inch). The water source can be either a water truck, tank, or a tundra pond (do not use salt water). Flush toward a collection area, such as a natural depression or a trench (Tactic T-9) lined with Visqueen and shored with sandbags or Shore Seal boom (Tactic T-3). Workers may agitate the tundra surface while flushing by gently directing water flow with the discharge hose or by using a squeegee (Tactic T-12). Recover flush water by suction or pump (Tactic T-7) and dispose of properly.

The following are commercially available surfactants:

- Citrikleen
- Corexit
- Dawn detergent
- Eco/+
- Enviroglade
- NK-3
- SN-70

A surfactant is either added to the flush water or applied directly to the tundra at rates specified by the manufacturer. Dawn detergent was shown to remove the greatest amount of crude oil residue from tundra vegetation when used in bench-scale studies (Jorgenson and Cater, 1992). Corexit-treated tundra showed the greatest survival rates of wet tundra vegetation after one growing season (Jorgenson and Cater, 1992). Other commercial products may be available.

APPLICABILITY

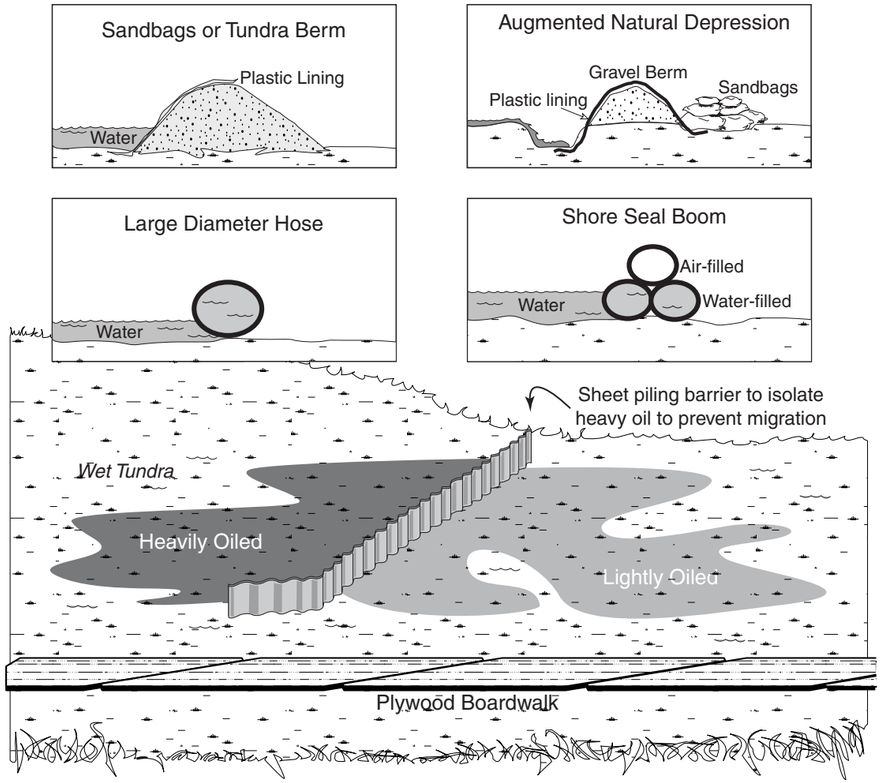
	APPLICABILITY	COMMENTS
SPILLED SUBSTANCE	Non-water-miscible substances (oil, fuel)	• Recovery of substances miscible in water will not be enhanced by surfactants.
TUNDRA TYPE	All	• Not recommended for frozen tundra.
SEASON	Spring, summer, fall	• Flushing is a viable option only when air temperatures permit.

CONSIDERATIONS AND LIMITATIONS

- Always use low-pressure and warm or cold water for flushing. High-pressure (>250 gallons per minute), hot-water (>106°F) flushing can cause extensive physical damage to tundra vegetation (Alaska Clean Seas, 1999).
- Skimmers will not be effective after surfactants have been applied to the site.
- If Dawn detergent is to be used, batches without foaming agents should be requested from the manufacturer. Excessive foaming can cause problems in the field (Jorgenson and Cater, 1992).
- Do not use saltwater for flushing, as salt will further damage tundra soils.
- To minimize physical damage to vegetation, do not flush more than 2 or 3 times in one area.
- Stay off of area being flushed.
- This tactic has been adapted from Tactic R-4 in the *Alaska Clean Seas Technical Manual* (Alaska Clean Seas, 1999, Vol. 1) and has been used in treating crude-oil-affected moist and wet tundra on the North Slope with acceptable short-term results (Jorgenson and Cater, 1992; Cater and Jorgenson, 1999). Information on the effectiveness of this tactic is based on a bench-scale study (Jorgenson and Cater, 1992) and field observations. No test data exist which document whether the use of this tactic results in long-term benefits to tundra restoration compared with other tactics, combinations of tactics, or “no action.”

EQUIPMENT, MATERIALS, AND PERSONNEL

- Water truck (2 operators per truck), tank, tundra pond – water source
- Surfactant – to dissolve spill residue
- Trash pump (2 operators per pump) – to pump water from source
- Suction hose (1 operator) – to take up water from water source
- Discharge hose (3- to 6-inch) with adjustable valve (1 operator) – to discharge water on site
- Mop, squeegee (1 operator) – to agitate and gently compress tundra mat to release spill residue
- Land barriers (Tactic T-3) (number of people needed is site-dependent) – to eliminate migration of flush-water off site; to provide collection point for flush water



Land barriers can be used for the following purposes:

- Contain and stabilize a contaminated area.
- Contain flood waters (Tactic T-1).
- Divert flush waters to a collection area and retain for recovery (Tactic T-2).
- Block water from migrating onto a site during draining (Tactic T-14).
- Augment a natural depression or a trench (Tactic T-9) to act as a containment area for recovery.

The type of barrier chosen depends on the site topography, tundra type, and treatment strategies. When flooding an area, contain it completely so that the water level may be elevated above the ground surface and the floating residue recovered. When using a barrier to prevent contaminant migration, form the barrier materials into a horseshoe shape downgradient of the flow. When capturing flush water for recovery, use barrier materials to augment a natural depression or a trench and direct flush waters in that direction.

Land barriers can be built with the following materials:

- Sand bags
- Shore Seal boom
- Large-diameter water-filled hose
- Sheet piling
- Tundra berms
- Gravel berms

APPLICABILITY

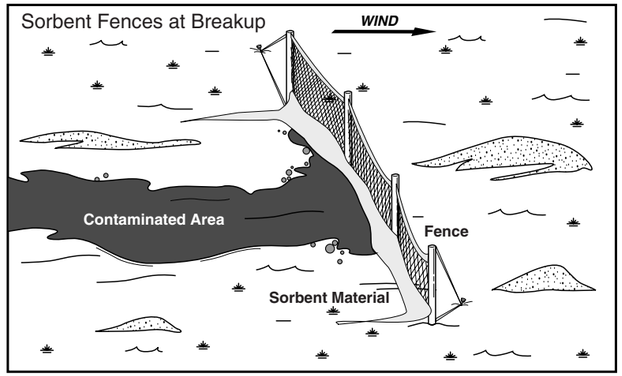
	APPLICABILITY	COMMENTS
SPILLED SUBSTANCE	All	• Water-soluble substances will tend to migrate vertically as well as horizontally in all tundra types. Subsurface barriers (such as sheet piling) may be appropriate to prevent subsurface migration of water-soluble spilled substances. • Non-water-soluble substances will tend to migrate horizontally (float) on wet and moist tundra, but will penetrate vertically into dry tundra.
TUNDRA TYPE	All	• Subsurface (vertical) migration of spill substances is more likely in dry tundra than other tundra types. • Subsurface pore spaces in moist and wet tundra are saturated with water and these tundra types, therefore, are relatively protected from vertical migration of non-water-soluble substances. Non-intrusive land barriers (e.g., sandbags, Shore Seal boom) are appropriate.
SEASON	All	• Shore Seal boom is particularly effective if frozen in place.

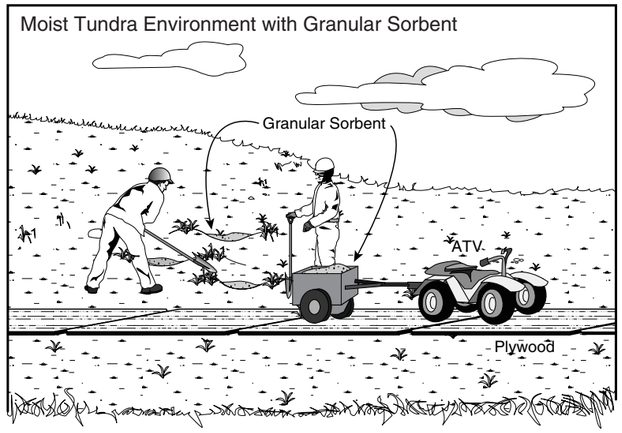
CONSIDERATIONS AND LIMITATIONS

- Use of vehicles on tundra must comply with applicable tundra travel policies (Tactic P-5).
- Land barrier techniques are appropriate for use on sites with low flow and shallow water.
- Disposal of construction material should be taken into account.
- Tundra (earthen) or gravel berms are the least desirable option for land barriers.
- Any digging should be a last resort and should be confined to as small an area as possible.
- All land barrier techniques described in this tactic (except sheet piling) have been adapted from Tactic C-4 in the *Alaska Clean Seas Technical Manual* (Alaska Clean Seas, 1999, Vol. 1). Sheet piling has been used with success on wet or moist tundra on the North Slope to prevent subsurface migration of contaminants (Cater and Jorgenson, 1995).

EQUIPMENT, MATERIALS, AND PERSONNEL

- Appropriate boom material (2 to 5 workers, depending on site) – to construct land barrier
- Backhoe (1 operator) – to build gravel or tundra berm
- Front-end loader with bucket (1 operator) – to move gravel or sand bags
- Floating pump and blower (2 operators) – to fill Shore Seal boom with air/water
- Visqueen or similar heavy plastic sheeting – to line gravel or tundra berms
- Sledge hammer – sheet piling installation





Sorbents can be used to pick up spill residuals from tundra. Determination of which sorbent material to use depends on the substance spilled, season, and availability. If water is not available for flooding or flushing, or if the site has a steep gradient or variable topography that cannot be boomed off effectively to contain flooding, spill residuals may be picked up with sorbents. The use of sorbents is labor-intensive. The physical damage to the tundra caused by deploying and recovering sorbent material must be carefully considered against the benefits of removing the residual.

Some examples of sorbent materials:

- Polypropylene sorbents (pads and boom material)
- Snow
- Granular sorbents (e.g., sawdust, cat litter)
- Straw

Use polypropylene sorbents on crude oil or oil-based substances directly on the tundra surface or on heavy sheen on standing water in wet or moist tundra or impoundments. Polypropylene sorbent boom can be fixed in position with stakes or fencing to collect floating product in wet tundra or to capture product floating on water draining off site.

Snow is a good sorbent material for recovering spill residues on tundra. Apply snow and recover snow/residue mixture using hand tools or heavy equipment (Tactic T-10) and remove for disposal. Other less absorptive materials like granular sorbents or straw may be used if snow is not available.

APPLICABILITY

	APPLICABILITY	COMMENTS
SPILLED SUBSTANCE	Crude oil, diesel, glycol, methanol, Therminol	• Fibrous polypropylene sorbents work well on fresh crude, light refined oils, and thick petroleum sheens, but are only partially effective on solidified or weathered oil, highly viscous oil, very thin sheens, or emulsified oil. • Sorbents are not effective for seawater or drilling fluid spills.
TUNDRA TYPE	All	• Prolonged labor-intensive work with sorbents on dry tundra may be counterproductive (dry tundra is most susceptible to physical damage and the effectiveness of sorbents can be fairly low).
SEASON	All	• Snow is a readily available sorbent in winter.

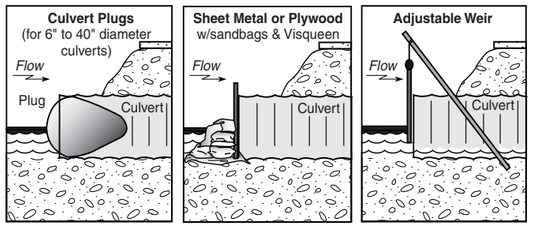
CONSIDERATIONS AND LIMITATIONS

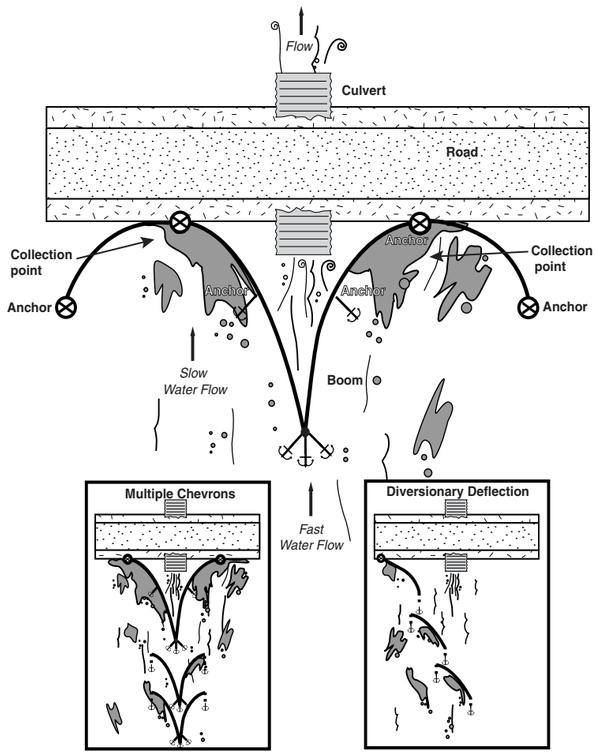
- Effectiveness depends on the particular sorbent and the physical properties of the residual spilled product.
- Snow, granular sorbents, and straw are not effective for spill residue floating on water.
- Using sorbents is labor-intensive.
- Use of sorbents generates a great deal of waste that must be disposed of properly.
- Sorbent wringers can be used to extend the life of fibrous polypropylene sorbents.
- The use of snow and polypropylene sorbent fence, boom, and pads has been adapted from Tactics R-2, R-8, and R-9 in the *Alaska Clean Seas Technical Manual* (Alaska Clean Seas, 1999, Vol. 1). Information on the effectiveness of this tactic is based on field observations, not controlled experiments. No test data exist which document whether the use of sorbents results in long-term benefits to tundra restoration compared with other tactics, combinations of tactics, or “no action.”

EQUIPMENT, MATERIALS, AND PERSONNEL

NOTE: Personnel typically work in pairs for sorbent deployment and recovery.

- Appropriate sorbent material – to collect spill residue
- Stakes or fencing – to secure sorbent boom to create a sorbent fence
- Shovels, rakes, pitchforks – for application and removal of granular sorbents
- Plastic bags or disposal drums – for collection of saturated sorbents
- Vehicle appropriate for tundra travel (optional) – to collect and transport saturated sorbent materials





Drainage protection may be appropriate during breakup and summer when contaminants may be mobilized and water is flowing through culverts, or while using other treatment tactics such as flooding (Tactic T-1) or flushing (Tactic T-2). Drainage protection will keep contaminants from migrating off site in water moving through culverts.

A culvert can be blocked using sheet metal, plywood barriers, inflatable culvert plugs, or adjustable weirs. Plywood or sandbags can also be used as culvert blocks, but are more labor-intensive. Place blocking materials over the upstream end of the culvert. Plastic sheeting over the outside of the block will prevent water penetration. Use a full block only when blocking of the water will not threaten the road or back water up so that additional tundra becomes contaminated.

When blocking a culvert is inadvisable because of the likelihood of washing out the road or flooding upstream uncontaminated areas, boom may be deployed in either chevron or diversionary configurations to allow water to flow while deflecting oil from the mouth of a culvert to collection sites along the road.

APPLICABILITY

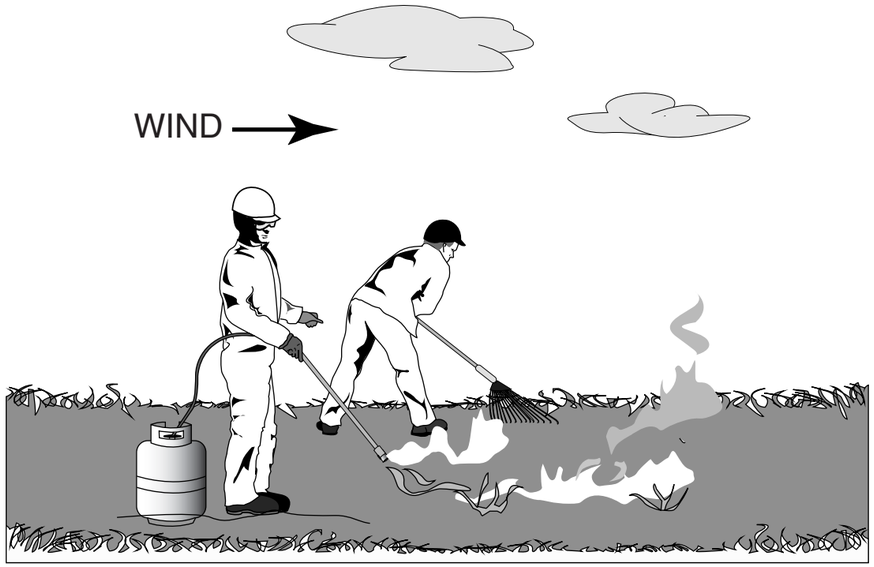
	APPLICABILITY	CONSIDERATIONS AND LIMITATIONS
SPILLED SUBSTANCE	All	• Boom systems will not protect drainage from water-soluble contaminants.
TUNDRA TYPE	All	• In dry tundra, consider need for drainage protection when flooding (Tactic T-1) or flushing (Tactic T-2).
SEASON	Spring, summer, and fall	• Pay particular attention to drainage protection during breakup.

CONSIDERATIONS AND LIMITATIONS

- This tactic has been adapted from Tactics C-2 and C-3 in the *Alaska Clean Seas Technical Manual* (Alaska Clean Seas, 1999, Vol. 1).

EQUIPMENT, MATERIALS, AND PERSONNEL

- Boom (2 workers) – to deflect floating contaminants from culvert
- Anchor system (2 workers) – to secure boom system
- Visqueen (2 workers) – to prevent seepage through permeable culvert blocks
- Inflatable culvert plug (2 workers) – to block culvert
- Sheet metal or plywood barriers (2 workers) – to block culvert
- Sandbags (2 workers) – to block culvert
- Air compressor (1 worker) – to inflate culvert plug
- Flatbed truck (1 worker) – to transport sandbags
- Front-end loader (1 worker) – to unload sandbags



Fire is a component of the tundra ecosystem, primarily for moist tundra. Burned tundra vegetation can regenerate, and as long as the roots and perenniating buds are left intact, recovery can be relatively rapid — 5 to 10 years. Sedges and grasses recover more quickly than mosses and lichens, which ordinarily must recolonize, while many vascular plants survive the fire.

This tactic is used to remove petroleum residue or other hazardous residues from a site following gross removal of the substance with other tactics. This tactic is not intended to remove pooled product from the ground surface. Heat generated while burning a pooled substance may cause vertical migration of the substance into the root mat or tundra soils, and could induce thermokarst.

One worker rakes contaminated vegetation with a metal rake so that grass and stems are oriented more or less vertically. A second worker uses a weed burner, which consists of a flame nozzle, hosing, and a propane tank. The flame nozzle is held just above the contaminated vegetation until the vegetation is burned down to stubble. Care should be taken not to burn vegetation down to ground level, which may damage the root system. Work is started on the upwind edge of the spill area and proceeds downwind so workers are not exposed to smoke. Fans may be used to increase burning efficiency, but should be considered only when the fire is controlled and will not spread to unaffected areas. Burn residue can be recovered with hand tools.

APPLICABILITY

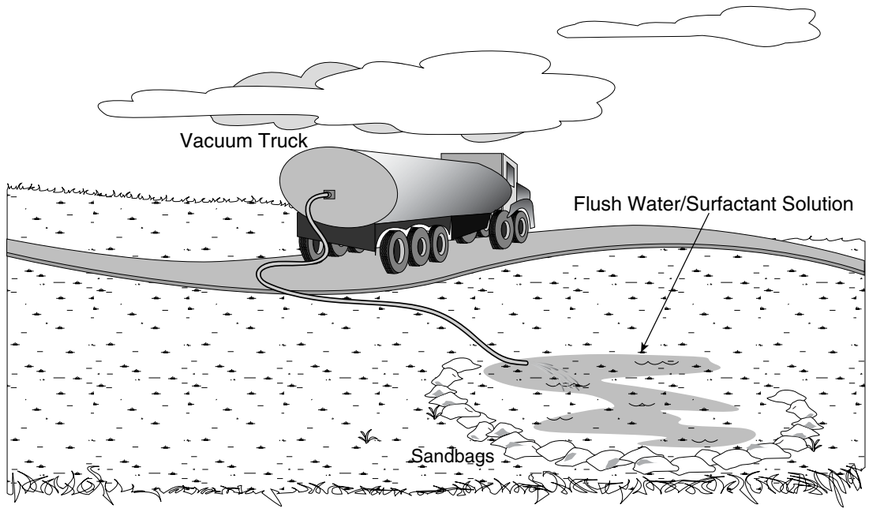
	APPLICABILITY	COMMENTS
SPILLED SUBSTANCE	Crude oil, fuels, glycol, methanol, Therminol	• Not effective for vegetation contaminated with drilling muds, produced water, or seawater. • If vegetation contaminated with weathered oil or fuel is burned, it may produce a residue that is difficult to clean up.
TUNDRA TYPE	All	• The drier the site, the more carefully the burn should be monitored to avoid damage to the root mat. Not recommended for dry tundra unless the root mat is wet or damp from rain or first flooded with water (Tactic T-1). Wet vegetation will still burn under the direct flame of a weed burner.
SEASON	All	• The least potential for damage to tundra root mat is during frozen conditions or when root mat is saturated with water.

CONSIDERATIONS AND LIMITATIONS

- Ensure spilled substance is flammable.
- Burn as soon as possible after a spill (before evaporation of volatile components of spilled substance).
- Follow proper safety procedures and use personal protective equipment, as required.
- Permission must be obtained from the Alaska Department of Environmental Conservation and potentially from the U.S. Environmental Protection Agency before burning tundra vegetation.
- This tactic has been adapted from Tactics B-2 and SH-10 in the *Alaska Clean Seas Technical Manual* (Alaska Clean Seas, 1999, Vol. 1) and has been tested on crude-oil-affected dry, moist, and wet tundra on the North Slope with acceptable short- and long-term results (McKendrick, 1978; Johnson and Viereck, 1983). Little test data exist which document whether the use of this tactic on *other spill types* results in long-term benefits to tundra restoration compared with other tactics, combinations of tactics, or "no action."

EQUIPMENT, MATERIALS, AND PERSONNEL

- Weed burner with propane tank (1 operator) – to ignite vegetation
- Metal rake (1 operator) – to orient oily vegetation
- Fire extinguisher (1 operator) – to suppress unwanted fire
- Fans (optional) – to increase burning efficiency



For spill sites off a road or pad, a vacuum truck can be used to drain an area (Tactic T-14) and to recover pooled spills, flood water (Tactic T-1), or flush water (Tactic T-2) from natural depressions, land barrier containment (Tactic T-3), or trenches (Tactic T-9). Place a hose in the impoundment while the truck remains on the road. A Super Sucker can be used for direct suction to remove liquids with solids (e.g., gravel) that vacuum trucks cannot handle.

A portable rope-mop skimmer can be used in calm water when non-miscible contaminants are floating on the surface. A rope skimmer is effective in any oil thickness and will pick up fresh oil, as well as oil that is somewhat weathered. Position the skimmer in the area of heaviest concentration of spill residue. A skimmer requires a power pack; a pump with suction and discharge hoses, and fittings; and a storage container for recovered product.

Submersible pumps or trash pumps can be used to pump areas that are not accessible by vacuum truck or Super Sucker. Submerge the pump or intake hose in the deepest area of an impoundment. Make sure the pump intake or hose end is fitted with a screen.

APPLICABILITY

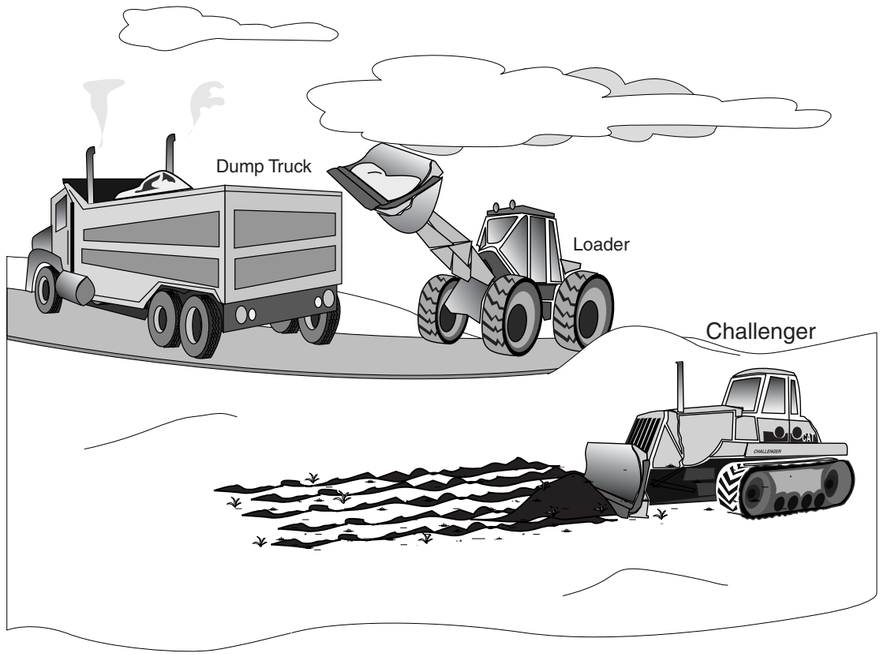
- *Spilled Substance:* All
- *Tundra Types:* All
- *Season:* All

CONSIDERATIONS AND LIMITATIONS

- Identify the disposal method or facility to be used and determine the volume requiring disposal before skimming or pumping an area.
- The effective range of a vacuum truck is 200 feet when removing viscous liquids such as crude oil, 400 feet when removing diesel or water.
- This tactic has been adapted from Tactics R-6 and R-8 in the *Alaska Clean Seas Technical Manual* (Alaska Clean Seas, 1999, Vol. 1).

EQUIPMENT, MATERIALS, AND PERSONNEL

- Portable rope mop skimmer (2 workers to deploy and maintain) – to remove floating product
- Power pack – power source for skimmer
- Pumps and hose (2 workers to deploy and maintain) – to suction
- Tank or tanker truck – to store or transport recovered product or water



Scraping the top 1 to 3 inches of surface contamination while the ground is frozen will reduce total contaminant levels on site. This tactic removes contaminated material while preserving some of the live roots, rhizomes, and stem bases of plants to allow for resprouting.

Using a tracked dozer, Bobcat or front-end loader, clear the area of snow (Tactic T-10) to expose tundra surface. Adjust the blade to remove the top 1 to 3 inches of vegetation. Pick up scraped vegetation manually or with the front-end loader. Transfer contaminated material to dump trucks on nearby roads and transport to appropriate waste disposal facilities.

APPLICABILITY

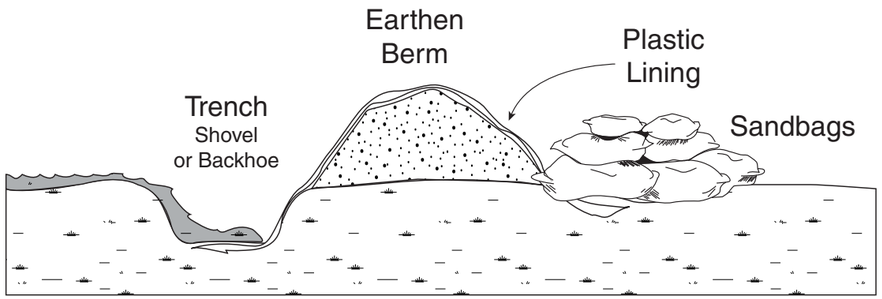
	APPLICABILITY	COMMENTS
SPILLED SUBSTANCE	All	• Most applicable for viscous subtances such as crude oil which will tend to be concentrated on the tundra surface.
TUNDRA TYPE	All	• May not be practical for areas with topographical relief (e.g., tussock tundra, patterned ground).
SEASON	Winter	• Only applicable when ground is frozen.

CONSIDERATIONS AND LIMITATIONS

- The goal of scraping is to remove heavily contaminated surface vegetation without impacting root mat or organic soils.
- Stockpiling snow on contaminated areas should be avoided. Snow piles will persist into the growing season.
- Use of vehicles and heavy equipment on tundra must comply with applicable tundra travel policies (Tactic P-5).
- Scraping has been used to treat crude-oil-affected moist and wet tundra on the North Slope with acceptable short-term results (Jorgenson and Cater, 1992; Cater and Jorgenson, 1995). Information on the effectiveness of this tactic is based on field observations, not controlled experiments. No test data exist which document whether the use of this tactic results in long-term benefits to tundra restoration compared with other tactics, combinations of tactics, or “no action.”

EQUIPMENT, MATERIALS, AND PERSONNEL

- Challenger dozer/ Bobcat (1 operator) – to scrape snow and contaminated surface vegetation.
- Front-end loader (1 operator) – to transfer scraped material into end dumps.
- Dump truck (1 operator) – to transfer scraped material to disposal site.
- Rakes and shovels (1 operator per tool) – to recover scraped material.



Use a trench to intercept the migration of spilled material, to divert material around a sensitive area, or to capture flush-water for recovery. Dig trenches by hand or by using a backhoe or Bobcat trimmer.

Place a trench or series of trenches at right angles to the flow and angled slightly downhill to avoid excessive pooling. Place excavated material on downhill side of trenches. In dry areas, line the sides and bottoms of trenches with plastic sheeting. In wet areas, line the downhill sides of trenches. A trench can be flooded with water to inhibit contaminant penetration and to stimulate flow toward a recovery device.

Usually, a trench in tundra will be the last option for diversion or capture of water or migrating contaminants. Do not excavate a trench in an area where the excavation will cause more damage than benefit. Before excavating in tundra, check the depth to the permafrost. The depth of a trench is limited to the active layer. Do not excavate frost-laden soils, since the disruption of the permafrost could cause thermal erosion (thermokarst).

APPLICABILITY

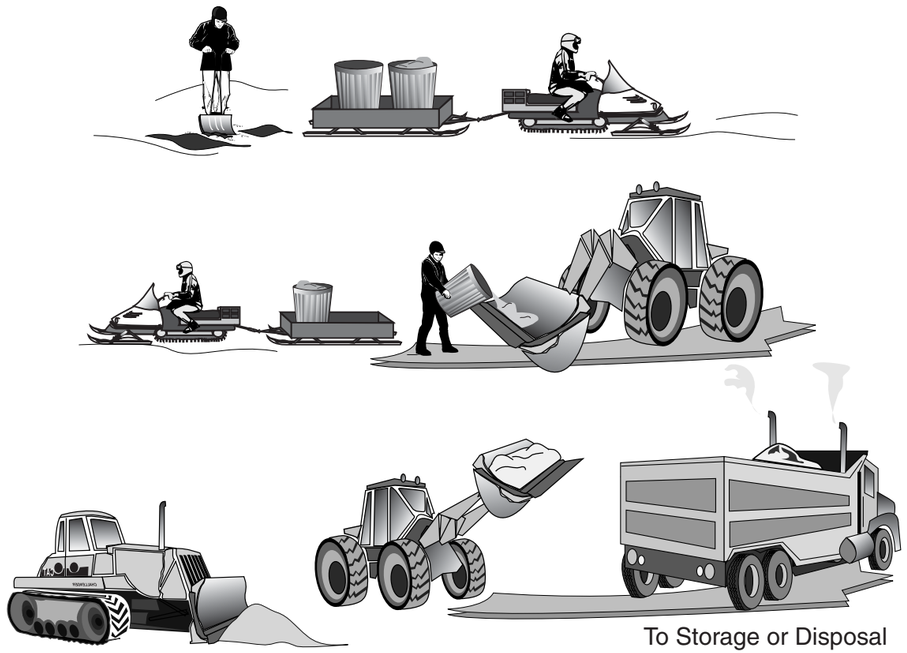
- *Spilled Substance:* All
- *Tundra Types:* All
- *Season:* All

CONSIDERATIONS AND LIMITATIONS

- Vehicle use on tundra must comply with applicable tundra travel policies (Tactic P-5).
- A Bobcat trimmer can cut about 4 inches maximum depth per cut. For depths of more than 8 inches, the trench must be as wide as the Bobcat. The Bobcat trimmer is the last option for trenching.
- A permit may be needed from the landowner before trenching.
- This tactic has been adapted from Tactic R-7 in the *Alaska Clean Seas Technical Manual* (Alaska Clean Seas, 1999, Vol. 1).

EQUIPMENT, MATERIALS, AND PERSONNEL

- Shovels (1 worker per tool) – to hand dig trench
- Backhoe or Bobcat trimmer (1 operator) – to dig trench
- Visqueen or similar heavy plastic sheeting – to line trench



Moving snow on or off a site may be useful for the following several reasons:

- Snow can be used as a sorbent (Tactic T-4) to clean up spill residue.
- Snow can be placed on a site to provide more water to plants during the growing season (Tactic T-15).
- Snow can be removed from a site to extend the growing season (Tactic T-20).
- Snow can be removed from a site so that contaminated vegetation may be scraped (Tactic T-8).

Snow can be handled with heavy equipment or by hand. Manual handling of snow is the preferred technique when working in tight areas, when the ground is too rough for heavy equipment, or when there is insufficient snow cover for heavy equipment. If the snow is contaminated with spill residue, it must be stored in a leakproof containment area and proper disposal must be arranged. If the snow is not contaminated with spill residue, it may be stockpiled nearby.

Broom and shovel the snow into piles. Transfer the piles to garbage cans, totes, or similar containers. Once a container is full, use a snow machine or Argo to transfer it to a stockpile or a truck on a pad or road.

APPLICABILITY

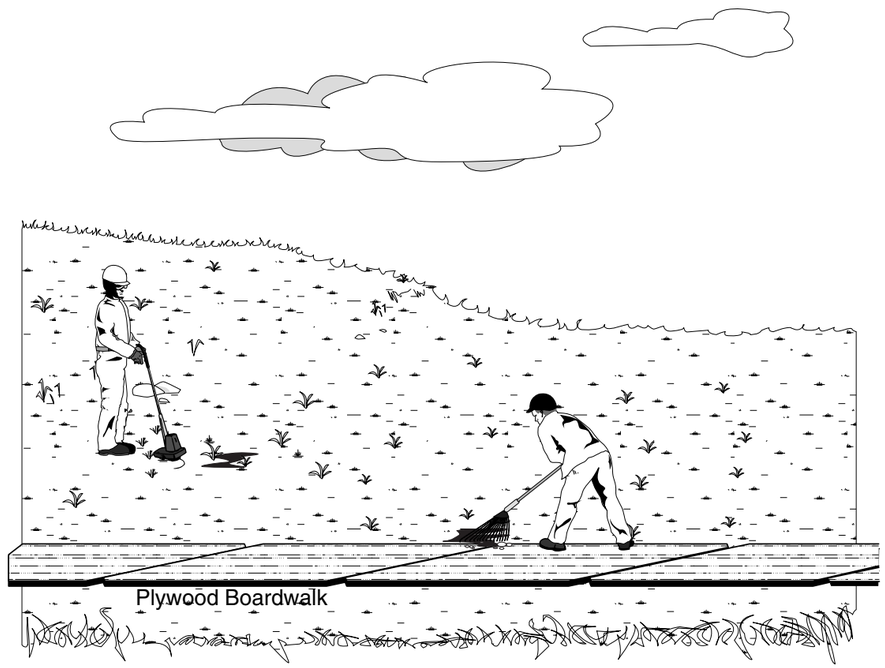
- *Spilled Substance:* All
- *Tundra Types:* All
- *Season:* Winter

CONSIDERATIONS AND LIMITATIONS

- Topographic relief (e.g., tussocks, patterned ground) may preclude use of heavy equipment.
- Use of vehicles on tundra must comply with applicable tundra travel policies (Tactic P-5).
- If snow is mixed with spill residue, arrange for lined containment and proper disposal before removing the snow.
- Add a spotter to each piece of heavy equipment when working in areas with above-ground pipes or other obstacles.
- This tactic has been adapted from Tactics R-2 and R-3 in the *Alaska Clean Seas Technical Manual* (Alaska Clean Seas, 1999, Vol. 1).

EQUIPMENT, MATERIALS, AND PERSONNEL

- Snow shovels and brooms (1 worker per tool) – manual snow removal
- Garbage cans or totes (1 or more workers per container, depending on weight of container) – to carry snow to trailer
- Snowmachine or Argo with trailer (1 operator) – to transport collected snow or containers
- Challenger (1 operator) – to scrape snow into piles for removal
- Front-end loader with bucket (1 operator) – to transfer snow to end dump
- End dump (1 operator) – to transport snow for storage or disposal



Cut and trim spill-affected surface vegetation to remove spill residue and dying or dead vegetation from the tundra surface. Remove contaminated plants to prevent remobilization of the spill residue and accelerate the recovery of the remaining plants.

Use cutting and trimming to remove foliage and stems only. Avoid damaging the plant roots. Collect the trimmed material by hand, rake, or shovel into collection bags, minimizing contact between contaminated and uncontaminated material.

APPLICABILITY

	APPLICABILITY	COMMENTS
SPILLED SUBSTANCE	All	• Most applicable to crude oil or diesel.
TUNDRA TYPE	All	• Wet and moist tundras are more resistant to physical damage than dry tundra.
SEASON	Spring, summer, fall	• Physical damage can be minimized by working in the spring or fall when the ground is frozen and vegetation is dormant.

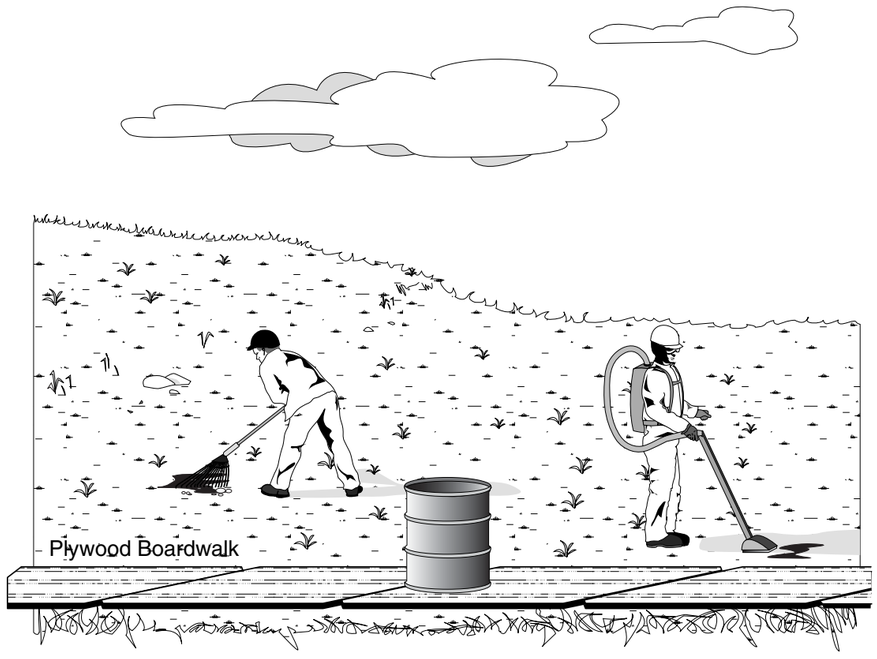
GENERAL CONSIDERATIONS AND LIMITATIONS

- This tactic has a high potential of physical impact to vegetation. Only surface vegetation should be removed. Root mat and surface structure should remain intact.
- This tactic is labor-intensive and may not be suitable for large sites where site access would cause long-term damage to areas unaffected by the spill.
- Cutting and trimming spill-affected vegetation have been used as part of the treatment strategy for crude-oil-affected moist and wet tundra sites on the North Slope with acceptable short-term results (Jorgenson and Cater, 1992). Information on the effectiveness of this tactic is based on field observations, not controlled experiments. No test data exist which document whether the use of this tactic results in long-term benefits to tundra restoration compared with other tactics, or in combination with other tactics, or in comparison with “no action.”

EQUIPMENT, MATERIALS, AND PERSONNEL

NOTE: Personnel typically work in pairs when cutting and trimming vegetation.

- Weed whacker
- Hand clippers or pruners
- Rakes (for collecting the trimmings)
- Trash bags
- Waste accumulation bins



Manual removal of spill residue may involve collecting spilled substances or contaminated debris by hand or with rakes, mops, pitchforks, trowels, shovels, buckets, portable vacuum systems, sorbent materials (Tactic T-4), and the like. Contaminated material can be placed directly in plastic bags or drums for transfer. If the containers are to be carried to temporary storage areas they should not weigh more than can be safely carried by one person.

A rubber squeegee (or other similar equipment) can be used to gently compress and agitate the tundra surface to squeeze contaminants out of pore spaces of the organic layer. Compression and agitation may be used in conjunction with flooding (Tactic T-1) or flushing (Tactic T-2) to enhance removal of spill residue.

During manual removal activities, avoid damaging plant roots and uncontaminated plants. The potential for physical damage to the tundra while using these labor-intensive techniques must be carefully weighed against the benefits of removing the spill residual.

APPLICABILITY

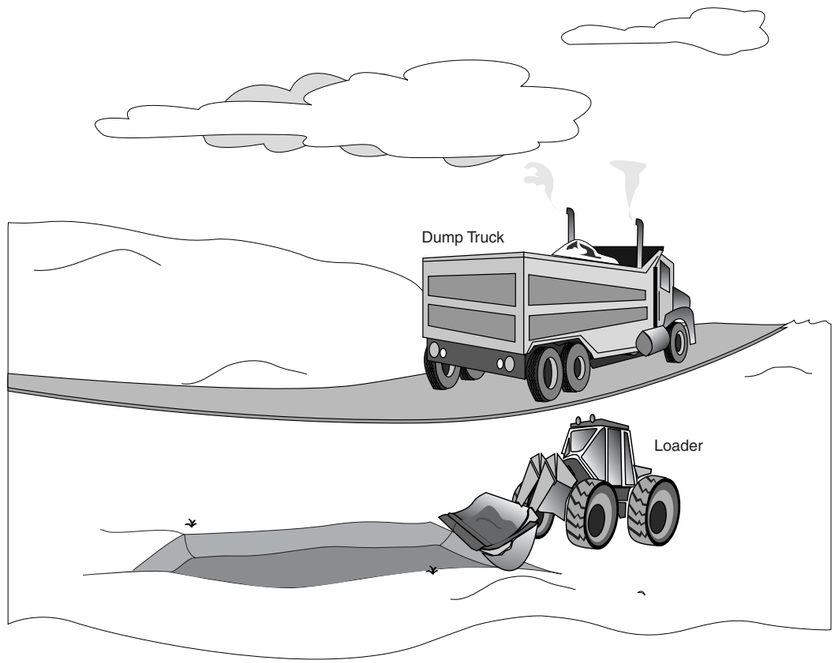
	APPLICABILITY	COMMENTS
SPILLED SUBSTANCE	Crude oil, diesel, glycol, methanol	• Not useful for spills of saline substances such as seawater.
TUNDRA TYPE	All	• Dry tundra is more susceptible to physical damage than wet or moist tundra.
SEASON	All	• Physical damage may be minimized when ground is frozen.

CONSIDERATIONS AND LIMITATIONS

- Take proper precautions to protect any type of tundra from foot/vehicle traffic (Tactic P-4).
- Not useful for spills of saline substances such as seawater.
- This tactic has been adapted from Tactics R-2 and SH-2 in the *Alaska Clean Seas Technical Manual* (Alaska Clean Seas, 1999, Vol. 1). Equipment such as mops or squeegees to swab, agitate, or compress the tundra surface to help remove crude oil from pore spaces has been used successfully on wet and moist tundra on the North Slope (Cater and Jorgenson, 1995). Information on the effectiveness of this tactic is based on field observations, not controlled experiments. No test data exist which document whether the use of this tactic results in long-term benefits to tundra restoration compared with other tactics, combinations of tactics, or "no action."

EQUIPMENT, MATERIALS, AND PERSONNEL

- Rakes (1 worker) – recovery
- Mop (1 worker) – recovery
- Squeegee (1 worker) – agitation
- Hand-carried vacuum unit (1 worker) – recovery



Excavation of spill-affected tundra soils may be necessary in extreme circumstances for rapid and complete removal of spill residuals. Excavation should be considered only when contamination levels are toxic to all plant growth (Tactic P-1) and when all other treatment options have been deemed ineffective or unpractical. This tactic generally results in more ecological damage and may require more aggressive rehabilitation than other treatment tactics. Since soil must be removed, a source of approved replacement material must be identified before excavation begins. Backfilling the excavation reduces thermokarst potential.

Dozers, excavators, and dump trucks can be used to excavate the organic mat and soils. An excavator removes contamination, either piling spoils directly into dump trucks or into lined stockpiles, which will be transported via front-end loader into dump trucks. Excavation should continue only as deep as the permafrost layer. Contaminated soil must be treated or disposed off site.

The depth of contamination determines the depth of removal. For highly concentrated spills of persistent materials, it may be possible to remove only the organic mat before spilled material migrates to mineral soil. Consider removing only "hot spots" and leaving as much tundra as possible intact.

Excavation of tundra may induce thermokarst, which may change the tundra environment and the kinds of plants that can grow on the site.

APPLICABILITY

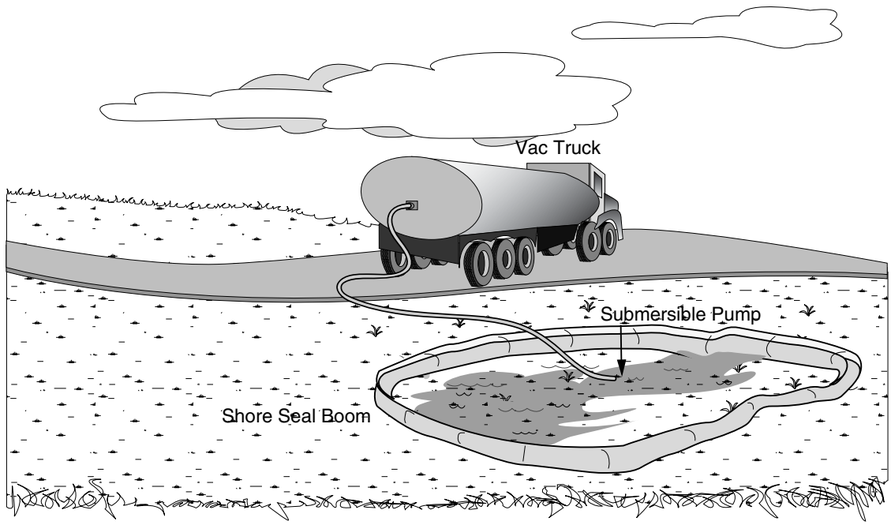
- *Spilled Substance:* All except saline substances
- *Tundra Types:* All
- *Season:* Spring, summer, fall

CONSIDERATIONS AND LIMITATIONS

- Excavation should be the last option to reduce contamination.
- Excavation must be limited to the active layer.
- Remove soil only to depth of contaminant penetration.
- Consider shipping/disposal options and required approvals before using this tactic.
- This tactic has been used to treat various North Slope tundra spills including spills of crude oil (Cater et al., 1996) and glycol (Kidd et al., 1997). Information on the short- and long-term effectiveness (or ineffectiveness) of this tactic is based on field observations, not controlled experiments. No test data exist which document whether the use of this tactic results in long-term benefits to tundra restoration compared with other tactics, combinations of tactics, or "no action." Generally, this tactic has been used to achieve a numeric chemical concentration (cleanup level) in the soil required by regulatory agencies.

EQUIPMENT, MATERIALS, AND PERSONNEL

- Front-end loader (1 operator per loader) – to transport
- Backhoe (1 operator and 1 spotter) – to dig, ensuring permafrost is not disturbed.
- Dump truck (1 operator) – to transport contaminated material to disposal site.
- Polyethylene sheeting – lining for stockpiles



Draining can be used during the growing season to reduce soil moisture and promote aeration of saturated tundra after spill residuals have been removed as much as possible or as much as desired. Aeration creates aerobic (oxygenated) soil conditions for plants and for soil microbes that may degrade the spill residuals.

Drain a site by blocking incoming water with land barriers (Tactic T-3) and pumping water from the site (Tactic T-7). Use or enhance topographical relief to create collecting points for pumps or vacuum trucks.

Place suction hoses in low areas where water collects. Suction may be required at many different areas of the site. If the site is inaccessible by vacuum truck and hose, all-terrain vehicles (ATVs) may be used to bring in small tanks or drums to collect the water (appropriate tundra travel permits required).

Trenches (Tactic T-9) may be needed to divert and collect water for pumping.

On-site water may need to be tested for contamination by spill residuals before draining. Proper approvals must be obtained for discharge or disposal of contaminated water from spill sites.

APPLICABILITY

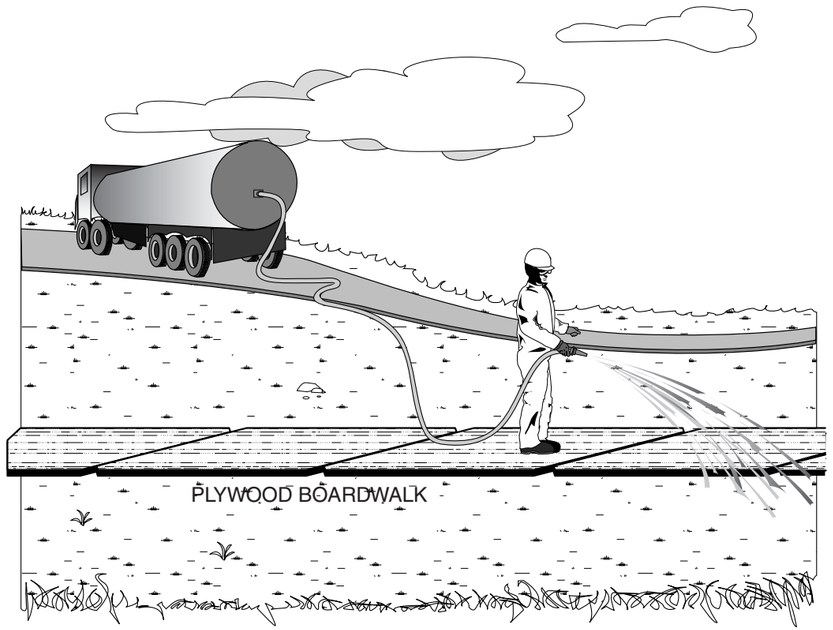
- *Spilled Substance:* All
- *Tundra Types:* Wet, moist
- *Season:* Spring, summer, fall

CONSIDERATIONS AND LIMITATIONS

- If floating product is present draining is not recommended; product may be introduced into soil pore spaces when water level is drawn down.
- Test water for contamination and consider disposal options and required approvals before using this tactic.
- Tundra must be thawed.
- Permanently draining a site could lead to thermokarst, depending on site conditions.
- This tactic has been used with short-term success to aerate crude-oil-affected moist or wet North Slope tundra (Cater et al., 1997; Burgess et al., 1996). Information on the effectiveness or ineffectiveness of this tactic is based on field observations, not controlled experiments. No test data exist which document whether the use of this tactic results in long-term benefits to tundra restoration compared with other tactics, combinations of tactics, or “no action.”

EQUIPMENT, MATERIALS, AND PERSONNEL

- Water truck (optional) (1 operator)
- Pumps (1 operator)
- Hoses (1 to 2 operators) – common sizes are 2- and 3-inch diameter
- Land barriers (Tactic T-3)



Irrigation is the application of water to increase the soil moisture to improve conditions for plant growth. Water is applied by flooding, spraying, or using sprinklers.

Flooding for irrigation can be implemented in the same manner as described for treatment flooding (Tactic T-1). Irrigation by flooding may require land barriers (Tactic T-3) to maintain desirable water levels. Flooding may be appropriate for rehabilitating wet and moist tundra dewatered during cleanup or treatment.

APPLICABILITY

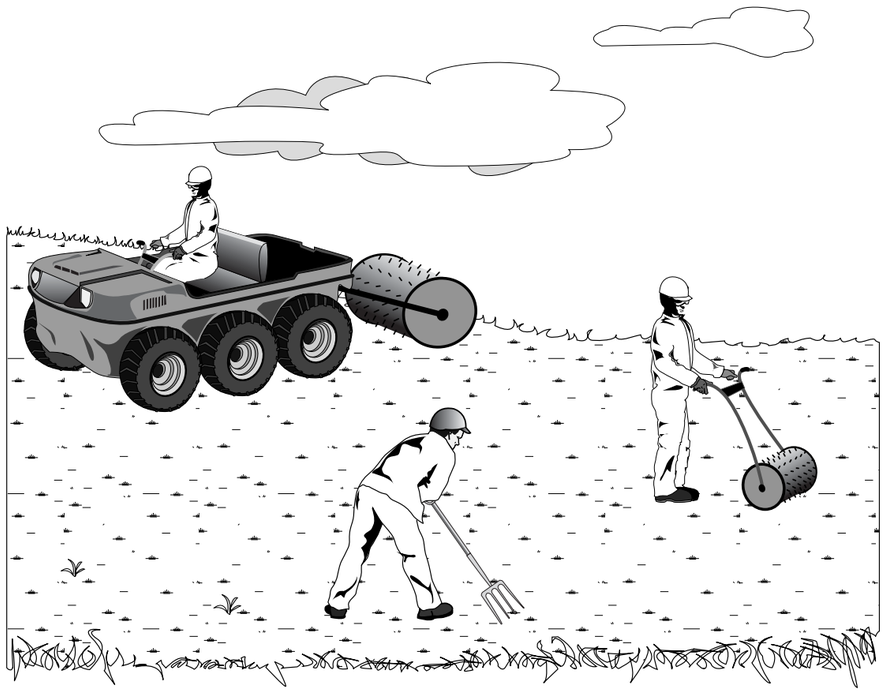
- *Spilled Substance:* All
- *Tundra Types:* All
- *Season:* Spring, summer, fall

CONSIDERATIONS AND LIMITATIONS

- This tactic is most applicable during the dry period of the growing season.
- This tactic has been used with success to increase water supply to crude-oil-affected moist or wet North Slope tundra (Cater and Jorgenson, 1994) during the growing season. Information on the effectiveness or ineffectiveness of this tactic is based on field observations, not controlled experiments. No test data exist which document whether the use of this tactic results in long-term benefits to tundra restoration compared with other tactics, combinations of tactics, or "no action."

EQUIPMENT, MATERIALS, AND PERSONNEL

- Water truck (optional) (1 operator)
- Pumps (1 operator)
- Hoses (1 operator) – common sizes are 2- and 3-inch diameter
- Sprinklers (1 operator)
- Clean water source (1 operator) – may be a nearby pond or creek



Aeration enhances vegetation growth and microbial degradation of spilled substances by increasing oxygen levels in subsurface soils. Aerate soils manually by repeatedly driving a pitchfork through the tundra root mat and into organic soils. Aerate soils mechanically by pushing or pulling a rotating barrel fitted with tines over the tundra. Tines should be long enough to penetrate the root mat and reach the organic soil horizon. Tilling (Tactic T-19) and draining (Tactic T-14) will also aerate soils.

APPLICABILITY

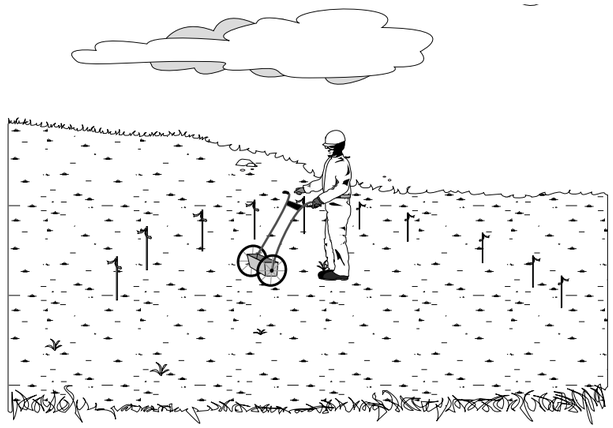
	APPLICABILITY	COMMENTS
SPILLED SUBSTANCE	All	• Low viscosity substances may migrate downward with aeration.
TUNDRA TYPE	All	• Most applicable on dry tundra sites. • Moist and wet tundra will be difficult to aerate without prior draining (Tactic T-14).
SEASON	Spring, summer, fall	• Most beneficial during growing season. • Difficult to penetrate root mat and soils when ground is frozen. • Low viscosity substances are more likely to infiltrate subsurface soils if spill occurs during thawed conditions.

CONSIDERATIONS AND LIMITATIONS

- Method of aeration will be determined by the size of a site and its topography.
- Mechanical aeration (with a rotating barrel) may not be practicable in tussock tundra.
- Use of vehicles on tundra must comply with applicable tundra travel policies (Tactic P-5).
- Aerate the active layer to the depth of contaminant penetration to stimulate microbial degradation of contaminant.
- This tactic has been used with success to increase oxygen supply to crude-oil-affected soils in moist or wet North Slope tundra (Cater and Jorgenson, 1994). Information on the effectiveness of this tactic is based on field observations, not controlled experiments. No test data exist which document whether the use of this tactic results in long-term benefits to tundra restoration compared with other tactics, combinations of tactics, or “no action.”

EQUIPMENT, MATERIALS, AND PERSONNEL

- Pitchfork (1 operator) – to punch holes through tundra surface
- Rotating barrel with tines (1 operator) – to punch holes through tundra surface
- Vehicle approved for summer tundra travel (1 operator) – to pull rotating barrel over tundra surface



Plants and microbes require three main soil nutrients for growth and reproduction: nitrogen, phosphorus, and potassium (N-P-K). Plants and microbes can take up these nutrients from fertilizers applied to the soil. Apply fertilizer to a spill site to:

- Enhance microbial populations and biodegradation of spilled substances.
- Stimulate growth of seeds, sprigs, or transplants.
- Increase vegetative cover and vigor of surviving plants.
- Encourage establishment of algae and mosses (primary communities), which will build organic matter in the soil and provide a nutrient base for other plants (McKendrick, unpublished data).

How to Apply

Broadcast fertilizer with a cyclone spreader (or by hand in small areas). The fertilizer either may be left to dissolve in water and percolate into the soil, or may be turned into the soil by tilling (Tactic T-19). Cyclone spreaders are commercially available in different capacities and models that can be pushed, pulled with a vehicle, or carried by one person on foot. Fertilizer may be applied simultaneously with seed (Tactic T-21) and soil amendments (Tactic T-18).

Even distribution of fertilizer may require some practice. One method is to measure and mark off a small area to be fertilized, fill the spreader with the amount of fertilizer appropriate for that area, and move in a grid pattern at a steady pace over the area multiple times until the spreader is empty. Calibrate the spreader before use.

How Often to Apply

Generally, only one application of fertilizer is enough to "jump start" the plants and microbes on a site. If a site shows no response to an application of fertilizer (within two growing seasons), it is possible that other problems need to be addressed (e.g., soil pH level, salt level, phytotoxic levels of soil contaminants).

How Much to Apply

The type of fertilizer to apply will depend on soil nutrient deficiencies. Determine nutrient deficiency by testing the soil on site and comparing it to background soil nutrient levels (Tactic AM-4). The fertilizer application rate will depend on the treatment goals for the site. If the goal is to enhance natural revegetation, the lower rate of the recommended application range is usually preferred, especially if a diverse community of plants is already established or desired. If the goal is to stimulate seeds or transplanted sprigs, a mid- to higher rate of the recommended application range may be appropriate. If the goal is to establish a dense stand of a single species of grass to prevent erosion, the highest rate of the recommended application range is appropriate.

Recommended Soil Nutrient Application Rates

NUTRIENT NEEDED	FERTILIZER TO BUY	NUTRIENT APPLICATION RATE (lb/acre)*		
		Wet Tundra	Moist Tundra	Dry Tundra
Nitrogen (N)	• Ammonium nitrate • Urea	40 to 120	70 to 180	50 to 160
Phosphorus (P_2O_5)	• Treble superphosphate	30 to 160	20 to 130	15 to 130
Potassium (K_2O)	• Potassium chloride • Potassium sulfate	40 to 180	40 to 180	40 to 180

*Nutrient application rate is not the *fertilizer application rate*. To figure out how much fertilizer to use, check the nutrient application rate on the table and divide it by the percent nutrient shown on the fertilizer package. Example: Ammonium nitrate contains 34% nitrogen. For wet tundra, nitrogen should be applied at a rate of 120 lb/acre. 120 / 0.34 = 353 pounds of ammonium nitrate per acre. (Source: unpublished information from Jay D. McKendrick)

APPLICABILITY

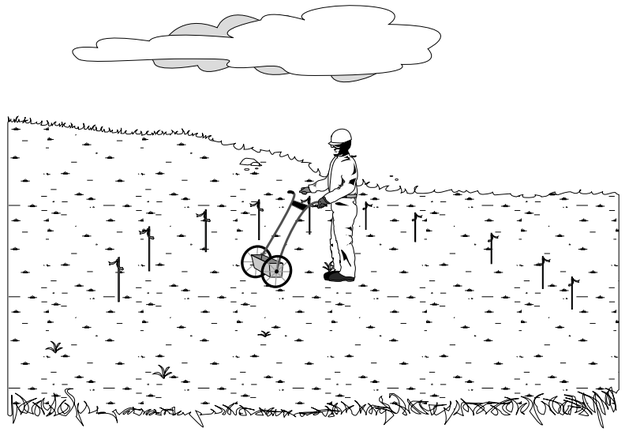
	APPLICABILITY	COMMENTS
SUBSTANCE	All	• Crude oil and diesel can make the soil hydrophobic (unwettable) and anaerobic (no air). These conditions must be corrected or overcome for fertilizer to be most beneficial.
TUNDRA TYPE	All	• Wet tundra can tolerate a heavier application of fertilizer than moist and dry tundra.
SEASON	Spring, summer, and fall	• Optimum season for fertilizer application is spring.

CONSIDERATIONS AND LIMITATIONS

- Fertilizers will not help vegetation if the spilled substance is present at phytotoxic levels in soils and root mat or if the substance made the soil pH or salinity conditions unsuitable.
- Excessive fertilizer application will burn vegetation and may kill some species.
- Fertilizers high in nitrogen may inhibit nitrogen-fixing, hydrocarbon-metabolizing microbes in soil (McKendrick, 1997a).
- Fertilizers high in phosphorus provide good initial plant establishment, but may decrease vegetation species diversity in the long term (McKendrick, 1997a).
- Use of vehicles on tundra must comply with applicable tundra travel policies (Tactic P-5).
- Arctic scientists have adapted for tundra treatment regimes the fertilizer practices used in temporal-zone horticulture and agriculture. Fertilizer has been used to treat a variety of disturbances and spills (crude oil, diesel, glycol) on wet and moist tundra with acceptable short-term success and variable long-term (crude oil only) success (Deneke et al., 1975; Shaver and Chapin, 1986; Kidd et al., 1997; McKendrick, 1999). Little data exist documenting the benefits of fertilizer use on dry tundra.
- Results of fertilizer use will vary according to tundra type and effects of the substance spilled. An *appropriately* fertilized wet tundra site may reach previous levels of plant cover and diversity up to 50 percent faster than a "no action" site (McKendrick, 1999).

EQUIPMENT, MATERIALS, AND PERSONNEL

- Necessary quantity of appropriate fertilizer
- Cyclone spreader (1 operator) – to broadcast fertilizer
- Vehicle approved for tundra travel (1 operator) – to pull a cyclone spreader over larger sites



Soil amendments can be used to improve or correct soil conditions compromised by spilled substances so that plants can grow. If soil testing (Tactic AM-4) shows that *extreme* pH or salinity conditions exist in the soil, applying an amendment may be appropriate. Tundra soils can be naturally acidic or saline (Tactic P-2). If the soil at the site is acidic or saline, but the levels are comparable to background test results, amendments should not be applied to the site.

Saline soil conditions cannot be corrected using gypsum or calcium nitrate solution unless adequate water supply and drainage (flushing) exists at the site.

Examples of Soil Amendments Used for North Slope Tundra

AMENDMENT	PURPOSE
Lime	To buffer overly acidic soil after a spill involving an acidic substance
Gypsum	Calcium source to remove salt (sodium and chloride ions) after a seawater or other type of salt spill
Liquid calcium nitrate	Calcium source to remove salt (sodium and chloride ions) after a seawater or other type of salt spill

How to Apply

Lime and gypsum are available in powder form and can be applied by hand or by using a cyclone spreader. Cyclone spreaders are commercially available in different capacities and models that can be pushed, pulled with a vehicle, or carried by one person on foot. Lime or gypsum may be applied simultaneously with fertilizer (Tactic T-17) and seed (Tactic T-21). Even distribution of powdered soil amendments may require some practice. One method is to measure and mark off an area to be amended, fill the spreader with the amount of powdered amendment appropriate for the given area, and move in a grid pattern at a steady pace over the area multiple times until the spreader is empty. Calibrate the spreader before use.

Liquid calcium nitrate can be applied to small sites using weed sprayers or watering cans, or to larger sites using a hydroseeder or some similar piece of equipment. The distribution method is similar to that of powders. A given amount of product is sprayed methodically over a given area to achieve even distribution at the correct application rate. Calibrate the spreader before use.

How Much to Apply

Application rates of soil amendments are site-specific and should be calculated by a soils laboratory. Provide the laboratory with a target pH range (background concentration), and the laboratory will calculate the application rate of a given soil amendment based on the site sample results. The manufacturer of liquid calcium nitrate will provide information on how much is needed (based on laboratory data) for a certain area to achieve a certain salinity range.

APPLICABILITY

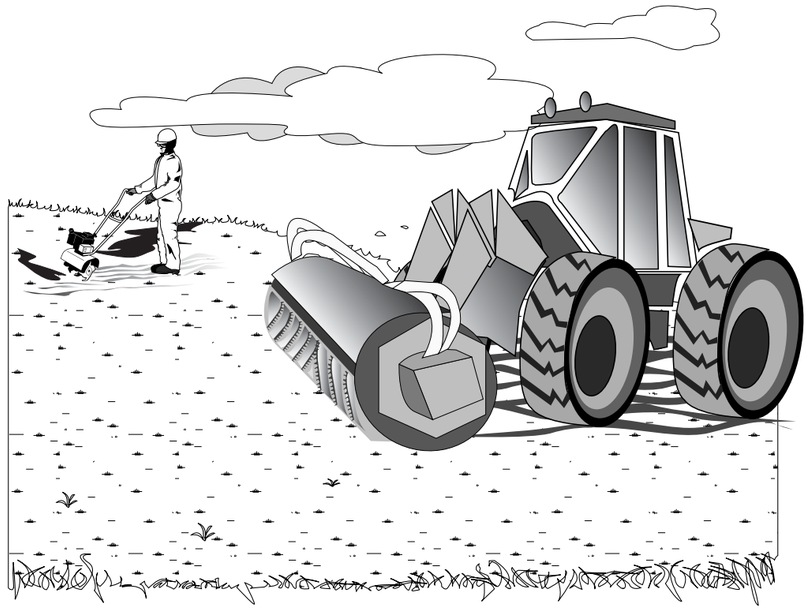
- *Spilled Substance:* All
- *Tundra Types:* All
- *Season:* Spring, summer, fall

CONSIDERATIONS AND LIMITATIONS

- Applying soil amendments to correct any but the most extreme soil conditions could have drastic effects on species composition and abundance.
- A site must have adequate moisture and drainage (either natural or mechanical flooding and drainage) in order to wash out sodium and chloride ions using gypsum or calcium nitrate solution.
- Soil samples must be sent to a soils laboratory, not a commercial analytical laboratory. (The University of Alaska Fairbanks Agricultural and Forestry Experiment Station has one.)
- Extremely alkaline tundra soils are not readily correctable with amendments.
- Arctic scientists have adapted for tundra treatment regimes the soil amendment practices used in temporal-zone horticulture and agriculture. This tactic has been used to correct soil pH or salinity conditions in North Slope wet and moist tundra soils with varying degrees of short-term success (Jorgenson and Cater, 1994; Reiley et al., 1995; McKendrick, 1996a). No test data exist which document whether the use of this tactic results in long-term benefits to tundra restoration compared with other tactics, combinations of tactics, or “no action.”

EQUIPMENT, MATERIALS, AND PERSONNEL

- Necessary quantity of appropriate soil amendment
- Cyclone spreader (1 operator) – to broadcast powdered soil amendments
- Vehicle approved for tundra travel (1 operator) – to pull a cyclone spreader over larger sites (optional)
- Weed sprayer or watering can (1 operator) – to spray liquid soil amendments on small sites
- Hydroseeder or similar equipment (2 operators) – to spray liquid soil amendments on larger sites



Tilling restores porosity and natural contours to tundra soils compacted by vehicle or foot traffic. Reworking contaminated soils can expose subsurface contamination and accelerate evaporation and other natural degradation processes. Tilling is appropriate after visible surface contamination and contaminated vegetation have been removed to the greatest extent possible.

The method of tilling will depend on size of the site. One person can use a rototiller in small, compacted areas. For larger areas, farm-type equipment such as discs, harrows, or plows may be needed. Earth moving equipment such as front-end loaders, graders, or bulldozers with scarifying or ripper teeth may also be used. Till deeply enough to mix and aerate the root mat and organic soil layer. After tilling, rake to re-establish soil contours, using surrounding tundra topography as a guide.

APPLICABILITY

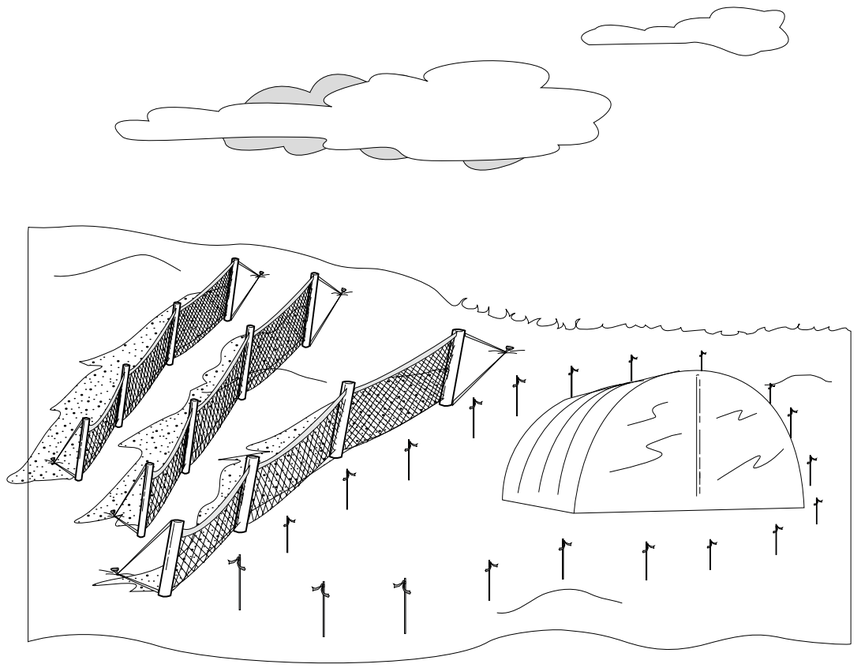
- *Spilled Substance:* All
- *Tundra Types:* All
- *Season:* Spring, summer, fall

CONSIDERATIONS AND LIMITATIONS

- Tilling is best for sites where there has been both compaction and deep infiltration of persistent substances (diesel, crude oil).
- Tilling will greatly disturb plant cover. Use only if soil has been highly compacted.
- The objective of tilling is to expose contaminants and promote their degradation, and also to reduce compaction.
- This tactic may not be appropriate for sites where wind or water erosion is a threat.
- Use of vehicles and heavy equipment on tundra must comply with applicable tundra travel policies (Tactic P-5).
- It may be necessary to a suitable seed bed for active seeding and natural recolonization.
- Tilling is a tactic adapted for tundra treatment from temporal-zone agricultural practices and has been used with acceptable short-term results in North Slope wet and moist tundra treatment regimes (Burgess et al., 1996; Cater and Jorgenson, 1999). Information on the effectiveness of this tactic is based on field observations, not controlled experiments. No test data exist which document whether the use of this tactic results in long-term benefits to tundra restoration compared with other tactics, combinations of tactics, or “no action.”

EQUIPMENT, MATERIALS, AND PERSONNEL

- Rototiller (1 operator) – to rework and aerate soil
- Front-end loader (1 operator) – to rework and aerate soil
- Grader with scarifying teeth (1 operator) – to rework and aerate soil
- Dozer with ripper teeth (1 operator) – to rework and aerate soil
- Rake (1 operator per rake) – to contour tilled soil



Extending the growing season enhances plant growth and microbial activity in tundra soils by increasing the amount of time the tundra is exposed to sunlight and thawing temperatures. The brief summers of the North Slope allow very little time for seeds to sprout and become established and for established plants to grow before freezing temperatures return in September.

The following techniques may be used to extend the growing season.

- ***Early spring snow removal:*** Scraping snow off the tundra surface (Tactic T-10) will speed spring thawing and promote plant growth and microbial activity. Snow can be removed by hand from small areas or with heavy equipment as long as the ground is frozen. Scrape snow off the tundra surface without disturbing the vegetation or root mat.
- ***Snow fencing:*** Snow fencing will keep snowdrifts off recovering sites and will speed spring thawing and promote plant growth and microbial activity. Snow fencing must be placed perpendicular to the prevailing winds, built approximately 4 to 8 feet high, and secured with guy-wires. Place one fence within several feet of the site, and stagger 2 or 3 rows of fencing behind it at 30- to 50-foot intervals. The length of the fences depends on the size of the site.
- ***Tenting:*** A tent can be constructed to create a snow-free, heated environment to enhance plant growth and microbial activity. This tactic can be used during spring, summer, and fall. A low tent made with clear polyethylene sheeting and lumber or metal frame can be inflated, heated, and ventilated with a forced-air heater unit.

APPLICABILITY

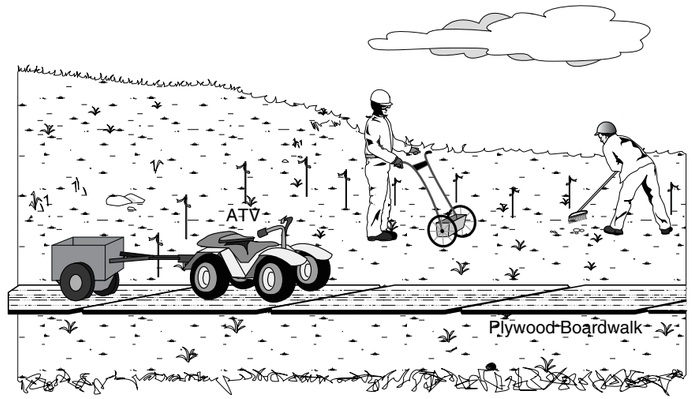
- *Spilled Substance:* All
- *Tundra Types:* All
- *Season:* All

CONSIDERATIONS AND LIMITATIONS

- Consider the trade-off between early snow removal and loss of insulating layer for vegetation while ambient temperatures are still relatively cool.
- Snow removal in early spring may limit the summer water supply on site. Irrigation (Tactic T-15) may be required during the growing season.
- Snow fencing left in place for more than a few growing seasons may change the plant communities impacted by the drifts.
- Tents and snow fences may require maintenance because of winds.
- Temperature and light levels in tented areas should be similar to growing- season conditions.
- Each technique identified for extending the growing season has been used in wet or moist North Slope tundra treatment regimes for diesel- and/or crude-oil-affected sites (Cater and Jorgenson, 1999) with varying short-term success. Information on the effectiveness or ineffectiveness of each technique is based on field observations, not controlled experiments. No test data exist which document whether the use of these techniques results in long-term benefits to tundra restoration compared with other tactics, combinations of tactics, or “no action.”

EQUIPMENT, MATERIALS, AND PERSONNEL

- Plastic snow fencing (available in 4-foot-wide rolls) (2 to 3 people to install) – stretch sheets between steel poles to block snow drifts
- Steel poles and means of installation (2 to 3 people) – to support plastic snow fencing
- Wire and stakes (2 people to set up, 1 person to maintain) – guy wiring to stabilize snow fences
- Polyethylene and metal or lumber frame material (3 to 6 people to build, 1 to 2 people to maintain) – construction materials for tent
- Forced-air heater (2 people to install, 1 person to maintain) – to provide heat and ventilation, and inflate tent



Seeding to revegetate damaged tundra can increase vegetative cover, help control thermokarst and erosion, improve site aesthetics, and develop root mat and organic matter to support growth of plant communities. Prepare the tundra surface by roughing it with a rake. Broadcast the seed using a cyclone spreader (or by hand in small areas). Rough the seeded tundra surface with a rake to work the seeds into the soil or the root mat. This technique will increase seed contact with the soil or organic matter and provide some protection from birds. Cyclone spreaders are commercially available in different seed capacities and models that can be pushed, pulled with a vehicle, or carried by one person on foot.

Even distribution of seed may require some practice. One method is to measure and mark off an area to be seeded, fill the spreader with the amount of seed appropriate for the given area, and move in a grid pattern at a steady pace over the area multiple times until the spreader is empty. Calibrate the spreader before use.

The type of seed to use depends on the tundra type, material spilled, and goals of seeding. For instance, if the goal of seeding is to provide temporary vegetation cover on salt-affected moist tundra until the natural plant community can re-establish itself, the grass *Puccinellia arctica* is a reasonable choice. This plant is salt-tolerant, establishes quickly, and offers little competition to natural succession. The application rate may be adjusted depending on the goal. To protect against erosion, use a higher rate to quickly establish dense growth.

Planting a mixture of seeds may be appropriate if a diversity of plants is desired or if a site has varied topography (e.g., tussocks, patterned ground). For such a site, different seeds will be successful in different areas within the site. To calculate the application rate for a seed mixture, multiply the single-species rate of each seed type by the percentage of the seed to be used in the mixture. For instance, if using a mixture of 50% *Poa glauca* (5 lb/acre if used alone) and 50% *Festuca rubra* (9 lb/acre if used alone), the mixture would contain 2.5 lb/acre *Poa glauca* and 4.5 lb/acre *Festuca rubra*.

Examples of Seeds and Application Rates Used for North Slope Tundra Revegetation

PLANT NAME	WHERE TO GET SEED	TUNDRA TYPE	APPLICATION RATE* (lb/acre)	COMMENTS
Poa glauca	Commercially available	Dry and moist	5	Provides cover quickly when fertilized. Keeps other plants out. Does well in mineral soils.
Festuca rubra	Commercially available	Moist and wet	9	Provides cover quickly when fertilized. Keeps other plants out. Does well in mineral soils.
Arctagrostis latifolia	Commercially available	Moist and wet	4	Provides cover quickly when fertilized. Keeps other plants out.
Puccinellia arctica	Commercially available	Dry to wet	2	Salt tolerant. Provides cover quickly and offers little competition to natural succession.
Dupontia fisheri	Hand collect seed, or transplant (Tactic T-22)	Moist and wet	1	Salt tolerant.
Puccinellia langeana	Hand collect	Dry to wet	2	Salt tolerant. Provides cover quickly and offers little competition to natural succession.
Sedum rosea	Hand collect	Dry and moist	1	Salt tolerant.
Cochlearia officianlis	Hand collect	Dry and moist	2	Salt tolerant.
Elymus arenarius	Hand collect seed, or transplant (Tactic T-22)	Dry and moist	6	Salt tolerant.

*Based on 100 seed per acre coverage and application of single species (unpublished information from Jay D. McKendrick)

Commercial sources for seeds in Alaska include, but are not limited to, Plant Materials Center in Palmer, Alaska Garden and Pet Supply in Anchorage, Northern Native Seeds in Palmer, and Phillip Smith Associates in Palmer.

Hand-collect seed from stands of the desired species while the plants are in seed (the plants need not be adjacent to the site), and collect the seed heads or pods by hand into cloth bags. Dry the seed heads/pods in the cloth bags, and have the material threshed, cleaned, and tested for purity, germination, and weight by a commercial seed processor. Plant the seed, or seal in bags, and store in deep freeze for future use (it is not known how long native seeds will remain viable in storage). An advantage of collecting seed near the spill site is that the seed will be adapted to local conditions.

APPLICABILITY

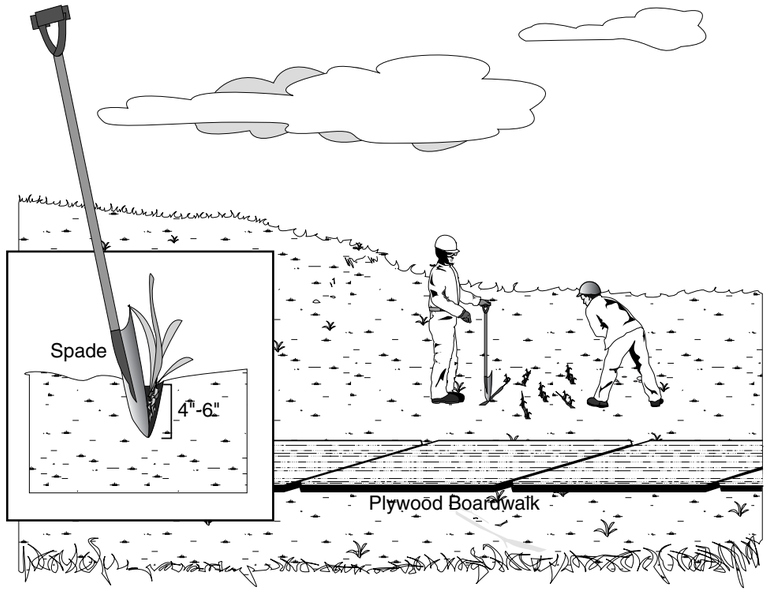
	APPLICABILITY	COMMENTS
SPILLED SUBSTANCE	All	• The seeds of some plant species tolerate crude oil or high salt levels.
TUNDRA TYPE	All	• Type of seed planted will depend on tundra type.
SEASON	Spring, summer, fall	• Preferable to plant near the beginning of the growing season, but not necessary.

CONSIDERATIONS AND LIMITATIONS

- Seeding success depends on soil conditions (nutrient availability, moisture, and contamination levels). Fertilizer (Tactic T-17), aeration (Tactic T-16), irrigation (Tactic T-15), and tilling (Tactic T-19) may help seeding success.
- Data on seed germination, purity, and weight are needed to determine application rates.
- Certain seeds are not salt-tolerant. If the site is near the coast or saline substances were spilled, test the soil for salt before seeding (Tactic AM-4).
- Seeding with spill-tolerant non-native species can provide short-term benefits (increased vegetative cover, erosion and thermokarst control), but may inhibit re-establishment of native plant communities (McKendrick, 1997a). Seeding with native species is currently preferred.
- Recently seeded sites may be attractive to birds and wildlife. It may be desirable to keep them — as well as humans — away from the site.
- Seeding has been adapted for tundra treatment from temporal-zone agricultural practices and has been used with good short-term results in North Slope wet- and moist-tundra treatment regimes (McKendrick and Mitchell, 1978; Kidd et al., 1997; Cater et al., 1997; Cater and Jorgenson, 1999). Limited test data exist which document whether the use of this tactic results in long-term benefits to crude oil-affected tundra compared with other tactics, combinations of tactics, or “no action.”

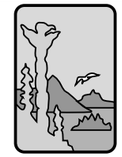
EQUIPMENT, MATERIALS, AND PERSONNEL

- Necessary quantity of appropriate seed, purchased or hand-collected
- Pruners, shears, other plant-cutting tools (1 worker per tool) – to hand-collect seed
- Cloth bags (1 worker per bag) – to collect and dry seed heads or pods
- Rakes (1 worker per rake) – to prepare tundra surface for seeding, cover seed after seeding
- Cyclone spreader (1 operator) – to broadcast seed
- Vehicle approved for tundra travel (1 operator) – to pull a cyclone spreader for larger sites



Transplanting (also called “sprigging”) is a method of introducing vegetation to a disturbed site when seeds are not readily available. Appropriate plants, usually wet tundra grasses or sedges, are taken from a similar area and replanted at the disturbed site. Generally, most wet tundra and aquatic grasses and sedges can be transplanted successfully. The above-ground portion of the plant may die back after transplanting, but the plant will regenerate from below-ground rhizomes and buds.

- Collect grasses or sedges in wet or aquatic areas by grasping the stem or group of stems as close to the ground as possible and pulling up. The roots must come up with the plant. This is not a concern for *Arctophila fulva,* which will regenerate roots when replanted.
- For moist or dry tundra areas where roots will not remain intact when plants are pulled up for transplanting, a bulb transplanter may be used to collect the above- and below-ground portion of a plant intact with a core of soil. Extrude the soil core/plant directly from the bulb transplanter into a slit in the soil.
- Collect the plants in a large plastic bag to keep them from drying out and transplant them as soon as possible.
- Clumps of grasses or sedges may be divided into many smaller sections (“sprigs”) for replanting. To plant sprigs, one person opens the ground with a long spade-shovel or similar tool, and another person inserts the plant’s roots or stem bottoms into the hole and steps on either side of the plant to secure it in the ground. In wet or aquatic areas, simply press the sprig into the soil or mud by hand.
- Transplant sprigs about 20 inches apart (closer if erosion is a threat). For larger areas, it may be practical to plant sprigs much farther than 20 inches apart.



Examples of Plants Used for Transplanting on the North Slope

PLANT NAME	TUNDRA TYPE	COMMENTS
Arctophila fulva	Wet (and Aquatic)	Salt tolerant
Caltha palustris	Wet (and Aquatic)	
Carex aquatilis	Wet	Resistant to crude oil
Dupontia fisheri	Moist and Wet	Salt tolerant
Elymus arenarius	Dry and Moist	Salt tolerant, only does well on sandy soil and dunes, offers little competition to natural succession
Eriophorum angustifolium	Wet and Moist	Resistant to crude oil
Hippuris vulgaris	Wet (and Aquatic)	
Menyanthes trifoliata	Wet (and Aquatic)	

APPLICABILITY

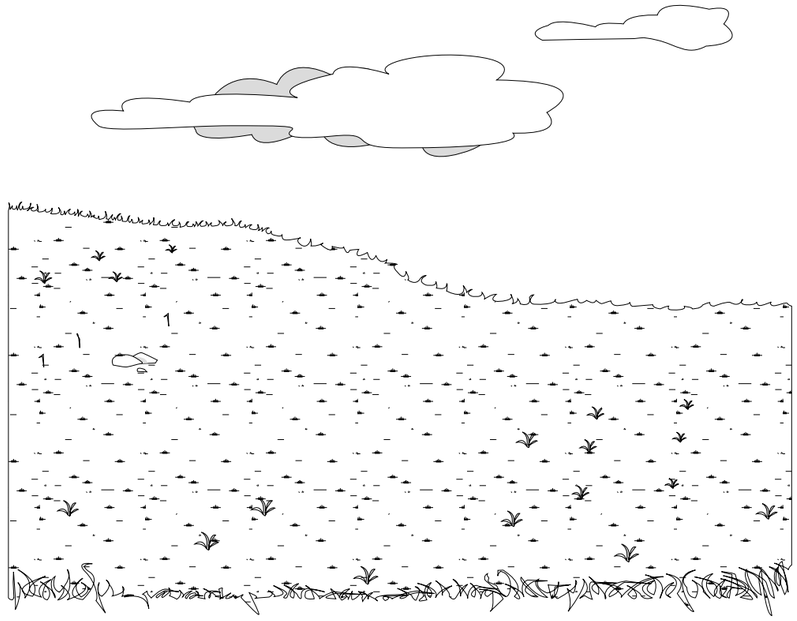
	APPLICABILITY	COMMENTS
SPILLED SUBSTANCE	All	• Some plants are resistant to oil or salt.
TUNDRA TYPE	All	• Type of transplant will depend on tundra type.
SEASON	Spring, summer, fall	• Thawed soil conditions are required.

CONSIDERATIONS AND LIMITATIONS

- If the site is near the coast or saline substances were spilled, test the soil salt level prior to transplanting (Tactic AM-4). Only certain plants are salt-tolerant.
- Species used must be adapted to transplanting. If the plant has a single tap root (an underground structure which cannot be divided without killing the plant) the species may not be easily transplantable.
- The advantage of transplanting over seeding is that transplants are usually readily available and transplanting can produce plant cover more quickly than seeding; however, transplanting is more labor-intensive. (Note that some species are only available as transplants.)
- Two people working together may be able to harvest sprigs and transplant up to 300 linear feet of shoreline or wet tundra in a 10-hour day (estimate extrapolated from Smith, 1988).
- Arctic scientists have adapted for tundra treatment the transplanting practices used in temporal-zone horticulture and agriculture. This tactic has been used with good short-term results on wet, moist, and, to a lesser extent, dry North Slope tundra on a variety of spill-impacted and physically damaged sites (McKendrick, 1993a; Herlugson et al., 1996; Kidd et al., 1997; Cater and Jorgenson, 1999). Information on the effectiveness of this tactic is based on field observations, not controlled experiments. No test data exist which document whether the use of these techniques results in long-term benefits to tundra restoration compared with other tactics, combinations of tactics, or “no action.”

EQUIPMENT, MATERIALS, AND PERSONNEL

- Large plastic bags – to carry and store collected plants
- Hand spade or shovel (1 operator, 1 planter) – to open hole in the ground to place sprigs
- Bulb transplanter or “core gun” (1 operator per tool) – to collect plants that cannot be readily pulled up from drier sites (optional – very small sites only)



Natural revegetation is the process of native plants re-establishing on disturbed or spill-affected sites through natural succession without seeding or planting. Natural revegetation is appropriate under any of the following conditions:

- Actions to prepare soil for seeding or planting may cause more physical damage and slower overall recovery than natural recovery.
- Establishing a ground cover quickly is not needed to prevent erosion from wind or runoff.
- The spill site is remote and soil preparation for seeding or planting are not practicable.
- Seeding or planting would interfere with eventual re-establishment of natural tundra plants.

Allowing a disturbed tundra site to revegetate naturally is generally preferred when the long-term goal is to restore natural tundra plant communities. In the long term, natural revegetation provides the best results for site aesthetics. Long-term observations have shown that manipulated sites (sites that are seeded and fertilized to provide quick ground cover) initially produce higher cover and density of vascular plants than unmanipulated sites (McKendrick, 1997a). Ultimately, however, the plant communities that become established at manipulated sites may differ from those that grew there previously.

The following tactics may be used to *enhance* natural revegetation:

- Apply fertilizer (Tactic T-17) to the perimeter of a spill site to increase the seed production and vegetative growth of the surrounding plant community (McKendrick, 1983b). The wind and wildlife can spread the seeds onto the site.
- Collect seed from adjacent appropriate stands of appropriate species and apply to site (Tactic T-21).
- Extend the growing season (Tactic T-20).

APPLICABILITY

	APPLICABILITY	COMMENTS
SPILLED SUBSTANCE	All	• More applicable for small amounts of non-persistent substances. • Crude oil and diesel can make the soil hydrophobic (unwettable) and anaerobic (no air). These conditions must be corrected for plants to establish.
TUNDRA TYPE	All	• Wet tundra recovers naturally from both physical and chemical damage more quickly than dry tundra.
SEASON	All	• See individual enhancement tactics for seasonal applicability.

CONSIDERATIONS AND LIMITATIONS

- Analyze soil properties (Tactic AM-4) to evaluate whether natural revegetation is feasible. (If the spill residual has created excessively acidic, alkaline, or saline conditions in the soil, adjacent native plants may not re-establish there.)
- Concentration of spilled substance in soils cannot be phytotoxic (plant-killing).
- Monitor the site (Tactic AM-5) for several growing seasons to evaluate revegetation trends. Note that as a recovering site goes through natural succession, the interim stages usually will not resemble the final community.
- Natural revegetation requires 15 to 30 years to restore the plant cover and diversity to pre-disturbance values.
- Using fertilizer on or near a site may encourage invasive “weedy” plants that can inhibit re-establishment of natural tundra plant communities.